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(54) **Ink jet printing apparatus.**

(57) Ink jet printing apparatus including a stationary print head (42,254) assembly including a multiplicity of individually actuatable ink jet printing modules (257) and apparatus for transporting a substrate (253) relative to and in operative spaced engagement with the stationary print head (42,254) assembly for printing.

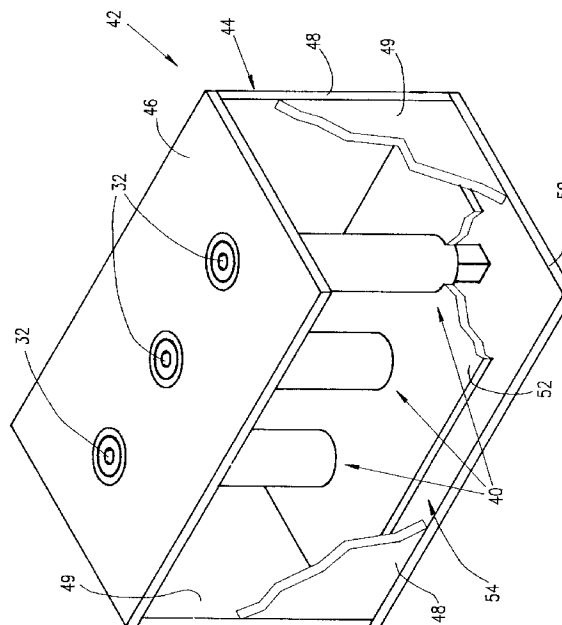


FIG. 2

FIELD OF THE INVENTION

The present invention relates to ink jet printing apparatus generally.

BACKGROUND OF THE INVENTION

There exists a very extensive patent literature relating to ink jet printers. Generally speaking there are two principal types of ink jet printers, continuous ejection ink jet printers and demand ejection ink jet printers.

Although conventional ink jet printers are extremely price competitive as compared with other types of high quality printers, they have a significant disadvantage in printing speed, as compared with laser printers. The disadvantage in printing speed results principally from the use of a moving print head having a relatively low line density of ink jet nozzles.

Conventional ink-on-demand thermal bubble ink jet and piezoelectric ink jet print heads employ a generally planar silicon, glass or metal base on which ink channels, firing chambers and capillaries are formed by photo imaging and etching techniques. This technique places inherent limitations on the line density of ink jet nozzles thereon.

SUMMARY OF THE INVENTION

The present invention seeks to provide an improved ink jet printer which overcomes the above-noted disadvantage of the prior art.

There is thus provided in accordance with one preferred embodiment of the present invention ink jet printing apparatus including a stationary print head assembly including a multiplicity of individually actuatable ink jet printing modules and apparatus for transporting a substrate relative to and in operative spaced engagement with the stationary print head assembly for printing.

There is also provided in accordance with one preferred embodiment of the present invention ink on demand ink jet printing apparatus including a print head assembly including a multiplicity of discrete individually actuatable ink jet printing modules and apparatus for transporting a substrate relative to and in operative spaced engagement with the print head assembly for printing.

Preferably the number of ink jet printing modules exceeds 100.

Additionally in accordance with an embodiment of the invention there is provided ink jet printing apparatus including a print head assembly including a multiplicity of individually actuatable ink jet printing modules extending over an entire writing dimension of a page and apparatus for transporting a page relative to the print head assembly for printing by the ink jet printing modules.

Further in accordance with a preferred embodiment of the present invention there is provided ink jet printing apparatus including a print head assembly including a multiplicity of individually actuatable ink jet printing modules and apparatus for providing relative motion between the print head assembly and a substrate to be printed, characterized in that relative motion between the print head assembly and the substrate occurs generally in only one dimension.

Still further in accordance with a preferred embodiment of the present invention there is provided ink jet printing apparatus including a print head assembly including a multiplicity of individually actuatable ink jet printing modules each comprising at least one capillary and apparatus for pressurizing ink within the at least one capillary for providing droplet ejection on demand and apparatus for providing relative motion between the print head assembly and a substrate to be printed,

In accordance with a preferred embodiment of the present invention, the apparatus for pressurizing ink comprises thermal apparatus for vaporizing ink within the capillary for providing droplet ejection on demand.

Additionally in accordance with a preferred embodiment of the present invention, the individually actuatable ink jet printing modules each comprise first and second capillaries which are at least partially nested within one another.

Further in accordance with a preferred embodiment of the present invention, each of the individually actuatable ink jet printing modules comprises an ink vaporization volume located within at least one capillary.

According to another preferred embodiment of the present invention, the apparatus for pressurizing ink comprises piezoelectric apparatus. Preferably the piezoelectric apparatus is disposed surrounding at least one capillary, preferably a single capillary.

In accordance with a preferred embodiment of the present invention, the multiplicity of individually actuatable ink jet printing modules are arranged in a staggered arrangement.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

Figs. 1A and 1B are respective sectional and partially cut away pictorial illustrations of an ink jet printing element constructed and operative in accordance with a preferred embodiment of the present invention;

Fig. 1C is a sectional illustration taken along lines C - C in Fig. 1B;

Fig. 2 is a partially cut away pictorial illustration of ink jet printing apparatus employing the printing

elements of Figs. 1A - 1C;

Figs. 3A and 3B are respective sectional and partially cut away pictorial illustrations of an ink jet printing element constructed and operative in accordance with a preferred embodiment of the present invention;

Fig. 4A is a simplified sectional illustration of part of an ink jet printing element constructed and operative in accordance with a preferred embodiment of the present invention and including a cylindrical piezoelectric element;

Fig. 4B is a simplified pictorial illustration of two alternative embodiments of the apparatus of Fig. 4A;

Fig. 5A is a simplified illustration of an ink jet printer including a stationary print head having a staggered array of printing elements in accordance with a preferred embodiment of the present invention;

Fig. 5B is a sectional illustration taken along lines VA,B-VA,B of Fig. 5A, when the ink jet printer is open; and

Fig. 5C is a sectional illustration taken along lines VA,B-VA,B of Fig. 5A, when the ink jet printer is closed.

DETAILED DESCRIPTION OF THE INVENTION

Reference is now made to Figs. 1A - 1C which illustrate the structure of an ink jet printing element constructed and operative in accordance with a preferred embodiment of the present invention. The ink jet printing element comprises an outer capillary 10, preferably formed of fused silicon and having an outer diameter of 363 microns and an inner diameter of approximately 150 microns.

Disposed interior of capillary 10 at one end thereof is an inner capillary 12, preferably formed of fused silicon and having an outer diameter of 144 microns and an inner diameter of 30 microns.

Capillaries 10 and 12 are commercially available from Polymicro Corporation of Phoenix, Arizona, U.S.A. The fit between inner capillary 12 and outer capillary 10 is such that the inner capillary may readily be inserted at an end of the outer capillary and such that ink leakage therebetween does not occur.

A polygonal solid fused silicon fiber 14, typically of rectangular cross section, having mutually insulated conductive coatings 16 and 18 on two surfaces thereof, is partially inserted into an end of outer capillary 10 opposite to that in which inner capillary 12 is located.

In accordance with a preferred embodiment of the present invention, the engagement between fiber 14 and the interior of outer capillary 10 is, as illustrated in Fig. 1C, such that at least one channel 20 is defined between the fiber and the inner wall of the capillary 10.

In accordance with a preferred embodiment of the

invention, fiber 14 is formed with a generally flat end facing and spaced from the corresponding facing end 24 of inner capillary 12. Preferably a resistor 22 is formed on the flat end in electrical communication with conductive coatings 16 and 18. The volume between resistor 22 and the corresponding end 24 of the inner capillary 12 defines a firing chamber 26 which receives an ink supply via channel or channels 20.

Electrical energy may be supplied to resistor 22 via conductive coatings 16 and 18 and corresponding conductors 28 and 30 coupled thereto, producing sudden heating of resistor 22 and corresponding vaporization of ink in the firing chamber 26, causing the formation of an ink vapor bubble inside firing chamber 26. The resulting expansion of the fluid within the firing chamber 26 causes ink within inner capillary 12 to be ejected as a droplet through the end opening 32, which defines a nozzle opening. Impingement of the droplet on a substrate, such as paper, produces desired marking thereon.

It will be appreciated that fiber 14 and conductive coatings 16 and 18 also operate as a heat conductor, for transmitting heat out of the firing chamber 26, so as to minimize the time required for ink vapor bubble collapse and thus maximize the duty cycle of the ink jet printing element.

Reference is now made to Fig. 2, which illustrates the mounting of a plurality of printing elements 40 of the type illustrated in Figs. 1A - 1C in a printing head 42.

The printing head 42 typically comprises a housing 44 including a nozzle plate 46 which engages the end 47 (Fig. 1B) of capillary 10 adjacent end opening 32, side plates 48, end plates 49 and a bottom plate 50. An intermediate plate 52 is disposed above and generally parallel to plate 50.

Each printing element is sealingly mounted into a suitably sized aperture formed in plate 52 adjacent the end of capillary 10 opposite to end opening 32. The protruding end of fiber 14 sealingly extends through an appropriately sized aperture formed in plate 50, below which conductors 28 and 30 are bonded to corresponding conductive coatings 16 and 18 formed on the fiber 14.

The volume between plates 50 and 52 preferably defines an ink reservoir 54 which preferably has a relatively large capacity such as 200 cc. Because the bottom edge 56 of capillary 10 extends somewhat below plate 52 towards plate 50, as seen particularly in Fig. 1A, a secondary ink feed conduit 58 is defined between edge 56 and plate 50. Ink is drawn by capillary action into the firing chamber 26 via channels 20 and conduit 58 from reservoir 54.

It is a particular feature of the present invention that the reservoir 54 preferably hold enough ink for printing thousands of pages, as opposed to the more limited ink reservoirs known in the prior art. This enhanced ink carrying capacity is made possible by the

fact that the print head 42 is stationary in operation in accordance with a preferred embodiment of the present invention.

Reference is now made to Figs. 3A and 3B which illustrate the structure of an ink jet printing element constructed and operative in accordance with another preferred embodiment of the present invention. The ink jet printing element comprises an outer capillary 110, preferably formed of fused silicon and having an outer diameter of 363 microns and an inner diameter of slightly less than 150 microns.

Disposed partially interior of capillary 110 at one end thereof is an inner capillary 112, preferably formed of fused silicon and having an outer diameter of 144 microns and an inner diameter of 30 microns.

Capillaries 110 and 112 are commercially available from Polymicro Corporation of Phoenix, Arizona, U.S.A. The fit between inner capillary 112 and outer capillary 110 is such that the inner capillary may readily be inserted at an end of the outer capillary and such that ink leakage therebetween does not occur. An outlet end 132 of inner capillary 112 is sealingly mounted to a top surface 146 of a print head housing 144, while a bottom end 133 of outer capillary 110 is sealingly mounted onto an intermediate surface 152 of the print head.

A round solid fused silicon fiber 114, having mutually insulated conductive coatings 116 and 118 on two surfaces thereof, is sealingly mounted via a relatively thick capillary 115 onto a bottom plate 150 of the print head and is partially inserted into an end of outer capillary 110 opposite to that in which inner capillary 112 is located. Fiber 114 is commercially available from Polymicro Corporation of Phoenix, Arizona, U.S.A.

In accordance with a preferred embodiment of the present invention, non-contact engagement is provided between fiber 114 and the interior of outer capillary 110, such that an annular channel 120 is defined between the fiber 114 and the inner wall of the capillary 110.

In accordance with a preferred embodiment of the invention, fiber 114 is formed with a generally flat end facing and spaced from the corresponding facing end 124 of inner capillary 112. Preferably a resistor 122 is formed on the flat end in electrical communication with conductive coatings 116 and 118. The volume between resistor 122 and the corresponding end 124 of the inner capillary 112 defines a firing chamber 126 which receives an ink supply via channel 120.

Electrical energy may be supplied to resistor 122 via conductive coatings 116 and 118 and corresponding conductors 128 and 130 coupled thereto, producing sudden heating thereof and corresponding vaporization of ink in the firing chamber 126, causing the formation of an ink vapor bubble inside firing chamber 126. The resulting expansion of the fluid within the firing chamber 126 causes ink within inner

capillary 112 to be ejected as a droplet through the end opening 132, which defines a nozzle opening. Impingement of the droplet on a substrate such as paper produces desired marking thereon.

It will be appreciated that fiber 114 and conductive coatings 116 and 118 also operate as a heat conductor, for transmitting heat out of the firing chamber 126, so as to minimize the time required for ink vapor bubble collapse and thus maximize the duty cycle of the ink jet printing element.

The overall structure of the stationary printing head may be generally similar to the structure shown in Fig. 2. Because the capillary 115 extends partially between plates 150 and 152, as seen particularly in Fig. 3A, a secondary ink feed conduit 158 is defined between edge 159 and plate 152. Ink is drawn by capillary action into the firing chamber 126 via channel 120 and conduit 158 from a reservoir 154.

Reference is now made to Figs. 4A-4B, which illustrate part of a printing element useful in piezoelectric demand type ink jet printing. A microcapillary 200, typically having a length of about 20 mm, an outside diameter of 0.3 mm and an inside diameter of 0.24 mm, has an inlet 202, narrowed to an inner diameter of about 0.03 mm, and a nozzle or outlet 204, narrowed to an inner diameter slightly less than the diameter of inlet 202. The inlet 202 may be coupled to an ink reservoir and the outlet 204 may be directed onto a substrate, such as paper, for printing thereon.

A piezoelectric generally cylindrical element 206, shown partly in solid lines and partly in broken lines in Fig. 4B, may be provided about the center of the microcapillary 200. The piezoelectric element may be operated so that when electrically actuated, it contracts, squeezing the microcapillary 200 and causing ejection of a droplet of ink from outlet 204. A suitable piezoelectric cylinder is readily realizable using conventional technology, while a suitable microcapillary is commercially available from Polymicrotechnology, Phoenix, AZ, USA.

Alternatively, the piezoelectric element 206 may be replaced by an element which is C-shaped in cross section, as shown in Fig. 4B in solid lines only, and therefore does not completely surround microcapillary 200. The C-shaped piezoelectric element may be bound to microcapillary 200 by any suitable bonding means. When an electrical pulse or pulses are applied to the piezoelectric element, it contracts and subsequently expands, creating a shock wave which operates on the ink inside microcapillary 200 and results in ejection of an ink droplet from outlet 204.

Reference is now made to Figs. 5A - 5C which illustrate an ink jet printer having a stationary print head constructed and operative in accordance with a preferred embodiment of the present invention. In general terms, the ink jet printer comprises a base 250 onto which is mounted a paper drive assembly 252,

such as a roller, which is operative to drive paper 253 to be printed past a stationary print head 254. A platen element 256 supports the paper 253 in a suitable orientation relative to the print head 254.

The stationary print head 254 may be identical to printhead 42 of Fig. 2 and preferably includes a staggered array 257 of printing elements such as those shown in any of Figs. 1A - 4B. The staggered arrangement is such that the printing elements are arranged along a plurality of mutually skewed rows, such as 6 rows. The amount of skew is such that adjacent ink droplets, provided by corresponding elements in adjacent rows, will appear to be continuous. If it is desired to print a solid line, the first element of the first row fires first, followed sequentially by the first elements of the second to sixth rows. Next, the second element of the first to sixth rows fire sequentially, and so on. It will be appreciated that the provision of a staggered array of printing elements enables spacing between adjacent dots in a printed line, i.e. printing resolution, to be much smaller than the minimum spacing between adjacent printing elements which is relatively large due to the relatively large diameter of the capillaries.

The printing elements may be staggered in any suitable manner. For example, 2400 nozzles may be provided which are operative to print a single line on A4 size paper at a resolution of 300 dots per inch. The 2400 nozzles may be positioned in 6 rows of 400 nozzles each, the distance between rows being 1/6 printing lines. The center to center distance between nozzles may be 1/60 of an inch or 423 micrometers, in order to provide the desired resolution of 300 dots per inch. Skew or staggering provided between corresponding nozzles on adjacent rows may be 423 micrometers.

The provision of discrete ink jet printing elements which need not be etched in a plane as in the prior art enables such a staggered arrangement to be realized. As a result, a stationary print head having a line resolution of 300 dots per inch or more across an entire page width may be readily realized. By using such a stationary print head, greatly increased print speeds, equal to or greater than those presently realized by commercially available laser printers, may be realized.

As shown in Figs. 5B and 5C respectively, the apparatus of Figs. 5A - 5C has opened and closed orientations. In the opened orientation of Fig. 5B, the paper, the platen element and the print head are not in touching engagement, thereby allowing the paper to be freely passed over the print head. In the closed orientation of Fig. 5C, the platen element retains the paper in close touching engagement with the print head, in order to facilitate accurate transfer of the ink to the paper.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has

been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims which follow:

Claims

1. Ink jet printing apparatus comprising:
 - a stationary print head assembly including a multiplicity of individually actuatable ink Jet printing modules;
 - means for transporting a substrate relative to and in operative spaced engagement with said stationary print head assembly for printing.
2. Ink jet printing apparatus comprising:
 - a print head assembly including a multiplicity of individually actuatable ink jet printing modules extending over an entire writing dimension of a page;
 - means for transporting a page relative to said print head assembly for printing by said ink jet printing modules.
3. Ink jet printing apparatus comprising:
 - a print head assembly including a multiplicity of individually actuatable ink jet printing modules; and
 - means for providing relative motion between said print head assembly and a substrate to be printed,
 - characterized in that relative motion between the print head assembly and the substrate occurs generally along only one dimension.
4. Ink jet printing apparatus comprising:
 - a print head assembly including a multiplicity of individually actuatable ink jet printing modules each comprising at least one capillary and means for pressurizing ink within said at least one capillary for providing droplet ejection on demand; and
 - means for providing relative motion between said print head assembly and a substrate to be printed.
5. Ink on demand ink jet printing apparatus comprising:
 - a print head assembly including a multiplicity of discrete individually actuatable ink jet printing modules; and
 - means for transporting a substrate relative to and in operative spaced engagement with the print head assembly for printing.
6. Ink on demand ink jet printing apparatus comprising:
 - a print head assembly including a housing

defining an ink reservoir and a multiplicity of discrete individually actuatable ink jet printing modules mounted on said housing in communication with said ink reservoir; and

means for transporting a substrate relative to and in operative spaced engagement with the print head assembly for printing. 5

7. Apparatus according to any of the preceding claims and wherein the number of ink jet printing modules exceeds 100. 10

8. Ink jet printing apparatus according to claim 4 and wherein each of said means for pressurizing ink comprises thermal means for vaporizing ink within said at least one capillary for providing drop let ejection on demand. 15

9. Ink jet printing apparatus according to claim 8 and wherein each of said individually actuatable ink jet printing modules comprises first and second capillaries which are at least partially nested within one another. 20

10. Ink jet printing apparatus according to claim 8 or claim 9 and wherein each of said individually actuatable ink jet printing modules comprises an ink vaporization volume located within at least one capillary. 25

11. Ink jet printing apparatus according to any of claims 4 and 8-10 and wherein said means for pressurizing ink comprises piezoelectric means. 30

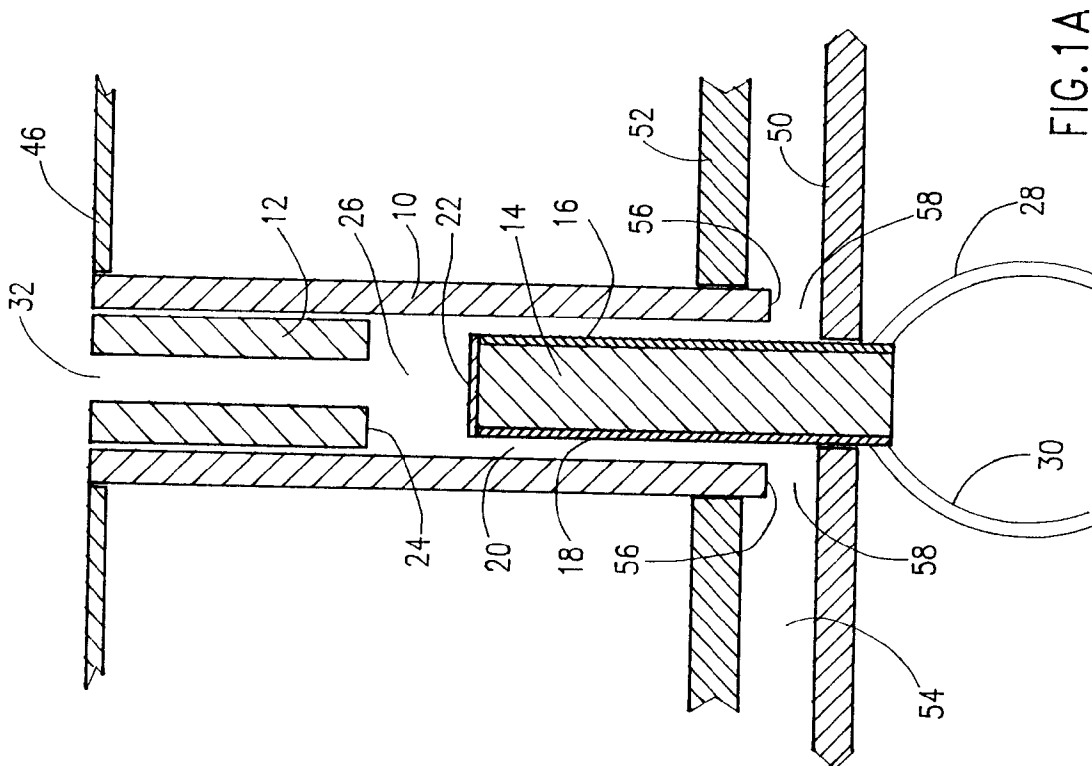
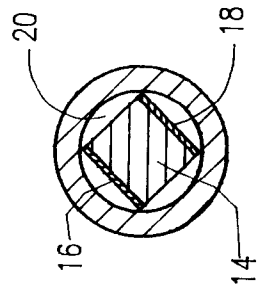
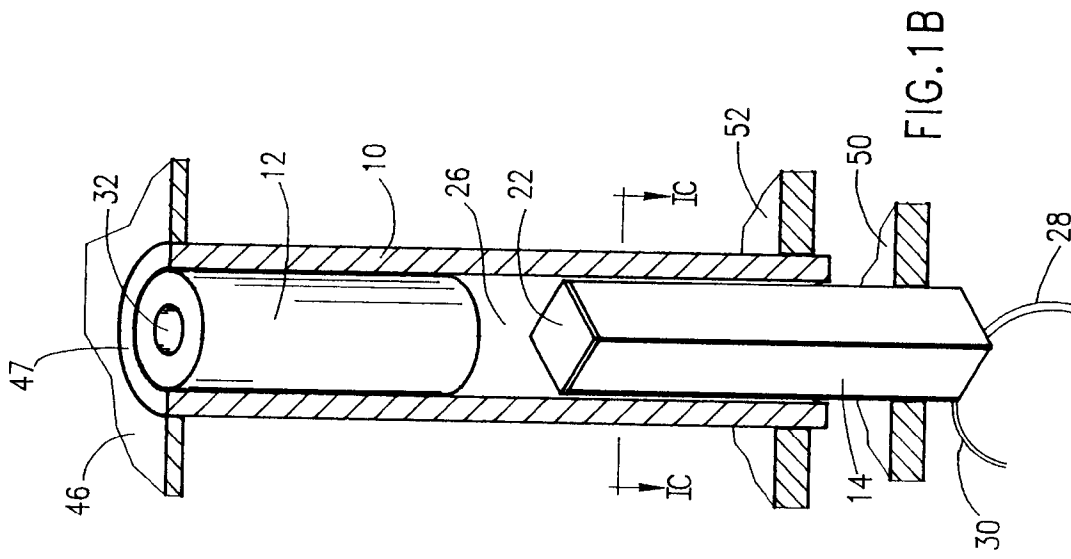
12. Ink jet printing apparatus according to claim 11 and wherein said piezoelectric means at least partially surrounds at least one capillary. 35

13. Ink jet printing apparatus according to any of claims 1 - 12 and wherein said multiplicity of individually actuatable ink jet printing modules are arranged in a staggered arrangement. 40

14. Ink jet printing apparatus according to claim 13 wherein the multiplicity of ink jet printing modules are arranged in a plurality of skewed rows such that ink droplets provided by corresponding elements in adjacent rows appear continuous. 45

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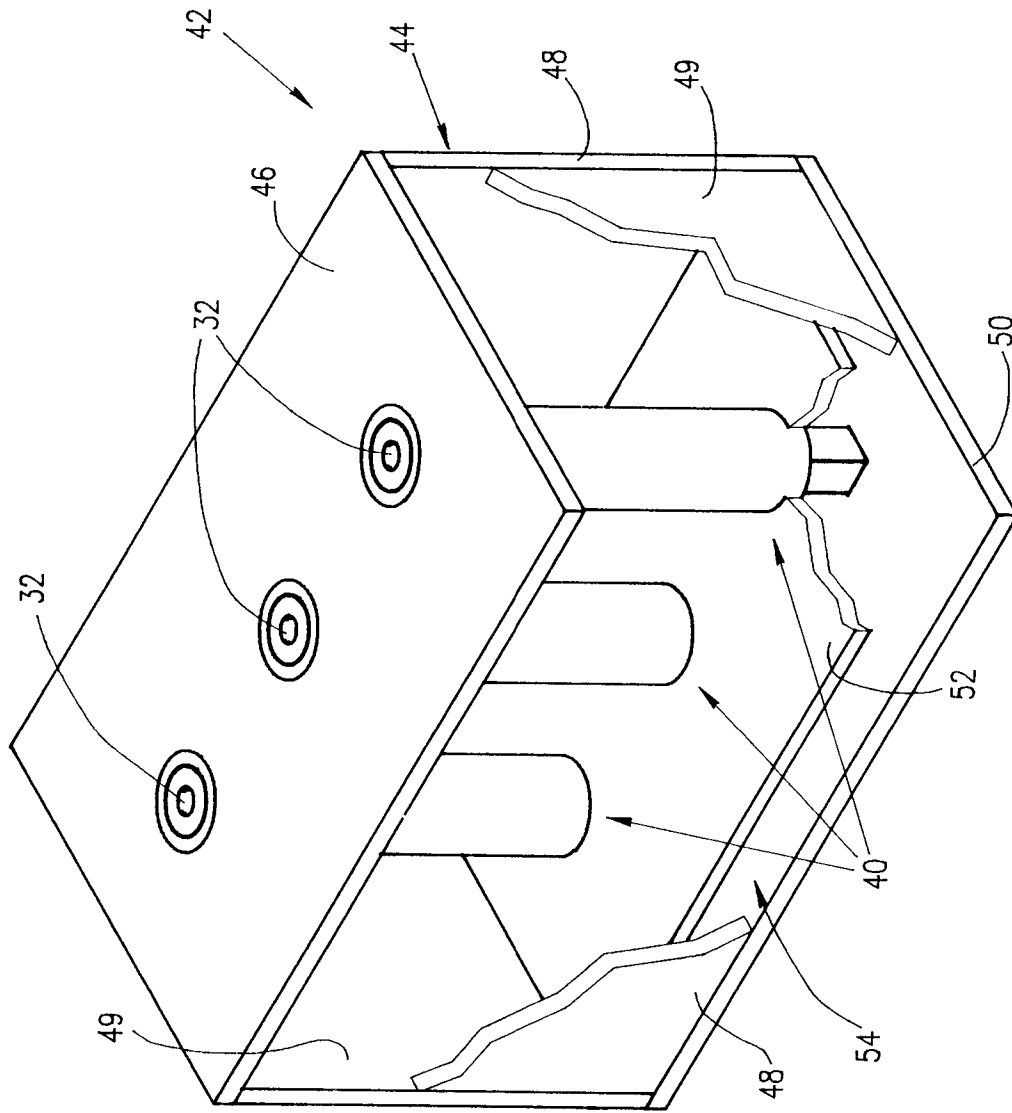
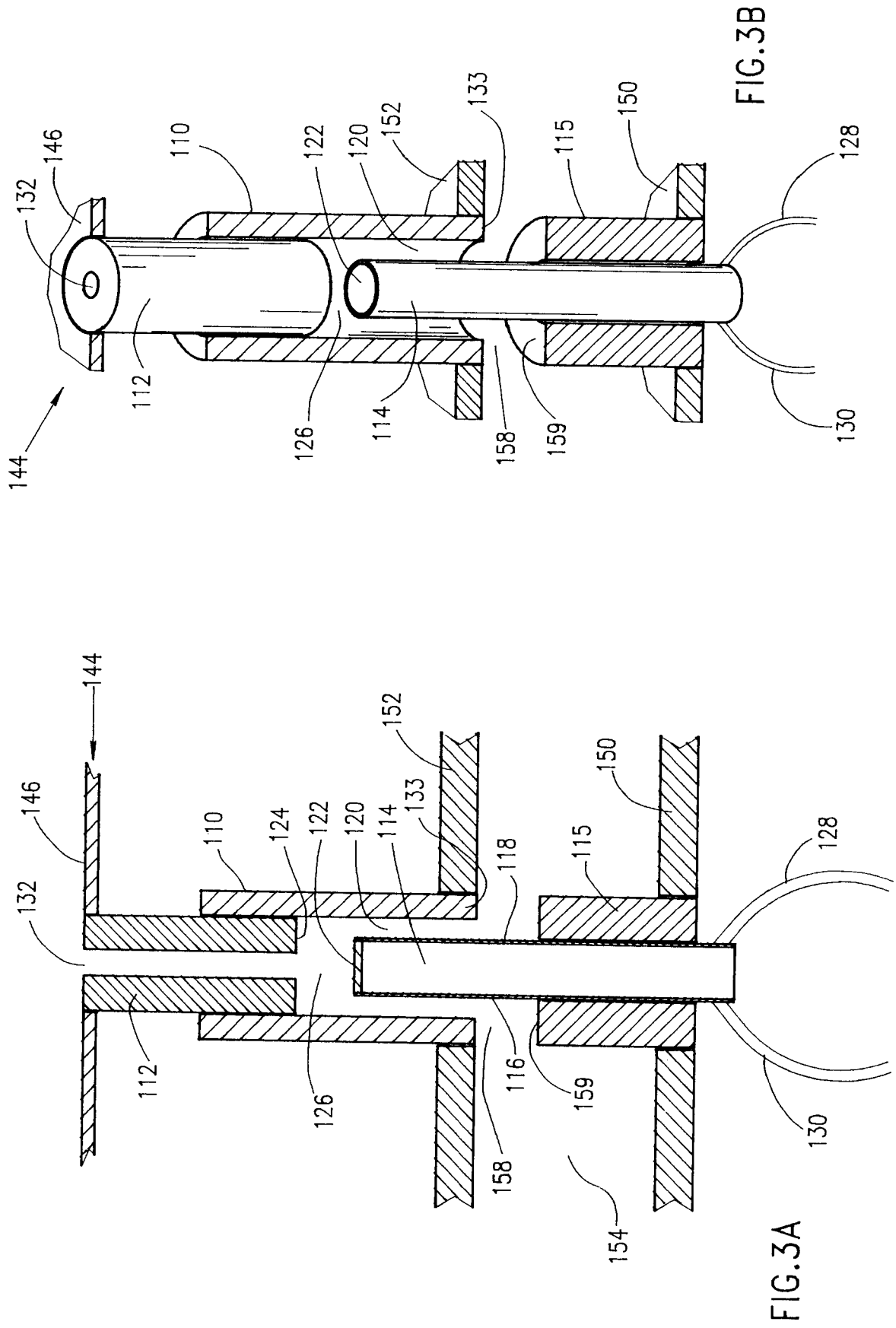
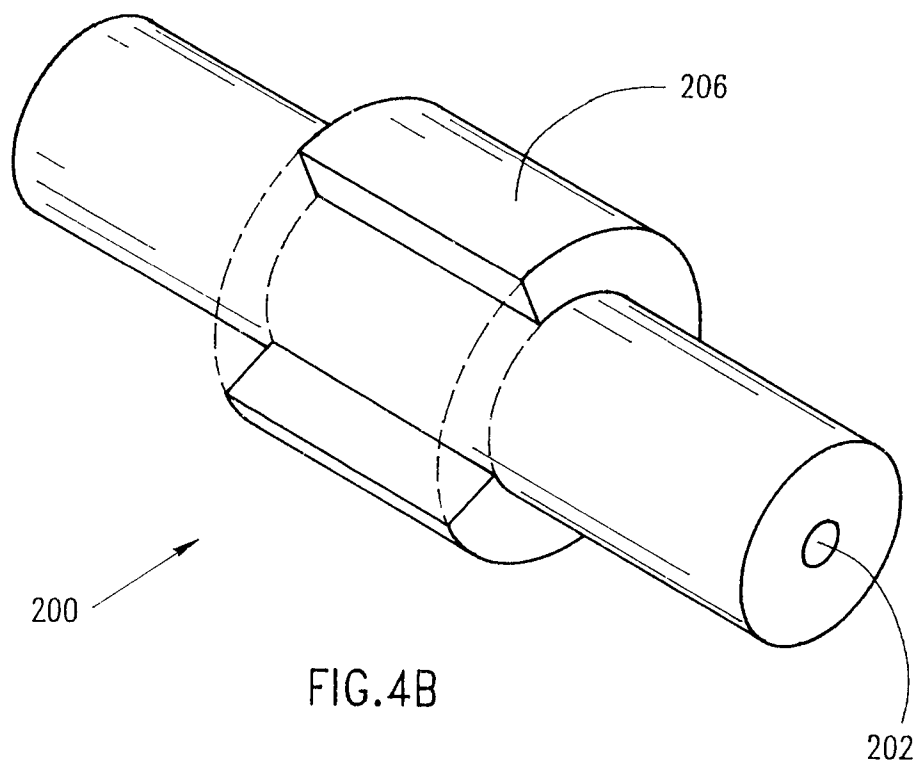
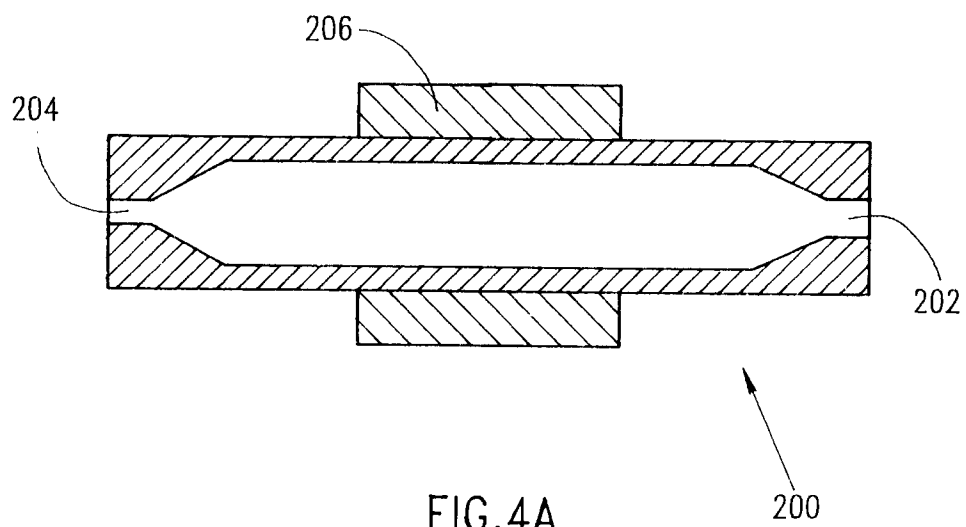


FIG. 2





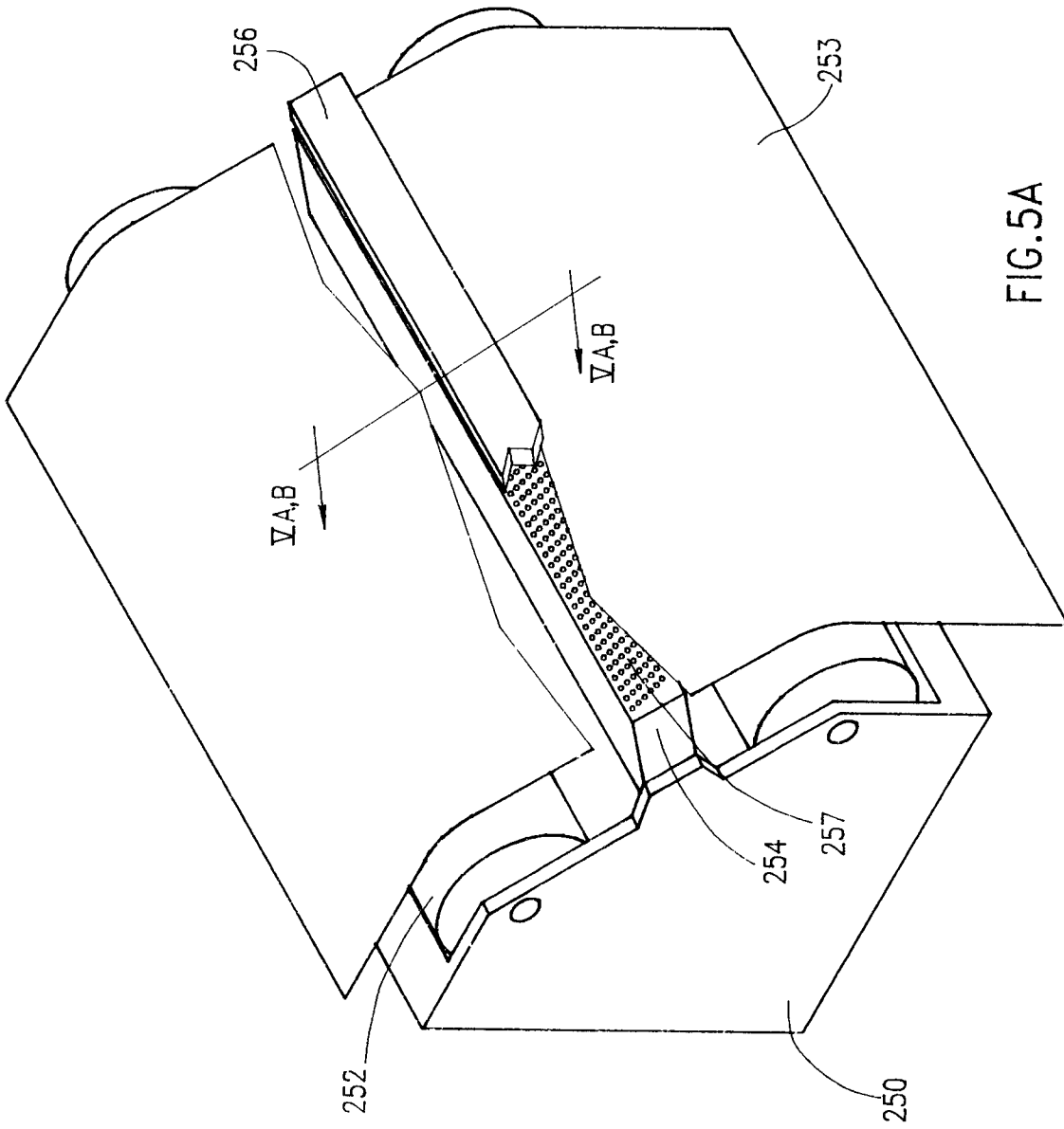


FIG. 5A

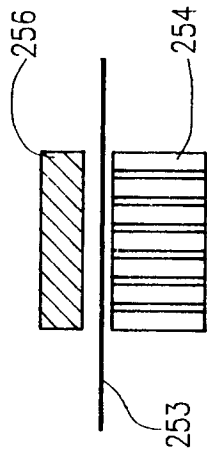


FIG. 5B

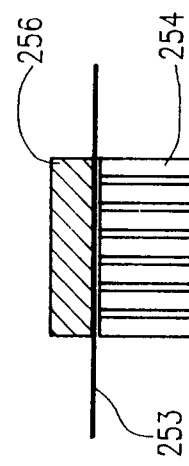


FIG. 5C



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 30 0071

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0 225 168 (DATAPRODUCTS CORP.) * the whole document *	1, 3, 5, 6 11, 13, 14	B41J2/155 B41J2/14
X	EP-A-0 014 918 (SMH-ADREX SA) * page 3, line 34 - page 7, line 33 * * figures 1-4 *	1-3, 8 13	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 365 (M-859)(3713) 15 August 1989 & JP-A-1 122 441 (H. MATSUMOTO) 15 May 1989 * abstract *	2	
A	EP-A-0 125 742 (HEWLETT-PACKARD CY.) * page 4, line 18 - page 5, line 12 * * figure 1 *	8, 10	
A	US-A-4 665 409 (M. BEHRENS) * the whole document *	11, 12	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B41J
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 19 MARCH 1992	Examiner VAN DEN MEERSCHAUT G
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